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CONIFER THINNING GUIDES IN FIVE STEPS

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ABSTRACT

Estimates for five elements, (a) the ring-per-inch growth rate potential, (b) the site index-basal area standard, (c) a size-merchantability limit forecast, (d) a proposed reentry period or cutting cycle, and (e) the minimum operable volume per acre, are used to suggest stems-per-acre and spacing standards for thinning operations. Ponderosa pine data are used to illustrate the thinning guides.

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KEYWORDS: thinning, spacing, stocking, plantation management, ponderosa pine.

Historically, foresters have lacked methods to make accurate predictions about stand response to thinning. Many thinned stands have failed to reach anticipated diameter growth levels because not enough trees were removed. We have failed to appreciate fully tree growth response potentials or have overestimated mortality rates. Improved systems are needed for estimating spacing-stocking-growth relations to insure a fuller recognition of tree growth potentials.

The time it takes to produce merchantable material in timber stands is critical from an investment viewpoint. This stress on time applies to both Government and industrial land managers. For example, the Forest Service Manual (2415.21, 1972) directs that "...rotations should be the minimum periods which will ensure reaching the timber size and quality objectives...." Thinning overstocked stands is imperative if time objectives are to be attained.

THINNING OBJECTIVES

Assuming no significant change in timber quality due to different stocking levels, an ideal schedule for thinning even-aged stands would have the general objective of producing merchantable size trees as rapidly as possible. Reaching the objective would require the forest manager to:

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1. Thin within a few years (perhaps 1 to 3) of the onset of inter-tree competition.
2. Thin precommercially twice. The first thinning would reduce initial stems per acre, not to the stocking level desired at first commercial thinning but to about 1-1/2 times this level. The surplus trees are needed to offset mortality, judgment errors as to form and release capacity, and utilization changes which reduce the merchantable size limit, i.e., increase the stems per acre stocking level objective. The excess trees may also provide shade to restrict limb and ground cover development, and generally ameliorate environmental stresses caused by the release cutting.

   The second thinning (after 3 to 5 years) is to select final crop trees and space them for fastest growth. Some managers may elect to combine these two thinnings into one.
3. Thin commercially the first time when a desirable percentage (perhaps 80 percent) of the stand has attained merchantable size.
4. Thin commercially as frequently as growth provides volumes sufficient to warrant harvesting operations without reducing the number of stems below the prescribed final harvest stocking level.

The onset of inter-tree competition has been one of the most difficult points to determine, yet this condition is the key to minimizing the time to reach the rotation size objective and to schedule thinning operations.

THE FIVE-STEP METHOD

If we know, or can estimate: (1) site diameter-growth potentials; (2) the basal area stocking level where inter-tree competition begins; (3) how much volume per acre is necessary to log profitably; (4) the cutting cycle; and (5) future tree size objectives, then thinned spacing and stocking levels may be calculated or shown graphically. The principles of the five-step method have general application when setting thinning standards. The approach differs from earlier ones (Gaines and Kotok 1954; Myers 1967) in that the upper limit of stocking (in basal area) is prescribed, while the level after thinning varies with size and time until the stand is reentered. This method is only intended for use until specific site data, such as from the western regional levels of growing stock studies for ponderosa pine and Douglas-fir (Myers 1967; Schubert 1971; Williamson and Staebler 1965, 1971; Bell and Berg 1972) are available.

Five factors need values in order to apply the five-step method to a particular site: (1) the ring per inch (RPI) growth rate potential; (2) the site index-basal area standard; (3) a size-merchantability limit forecast; (4) a proposed reentry period, or cutting cycle; and (5) the minimum operable volume per acre. Specific data for ponderosa pine are used to illustrate application of the method for one species.

Step 1.--Determining Growth Rate Potential

The growth rate potential in rings per inch (RPI) can be determined in several ways. Old stumps can provide good estimates of a site's breast height RPI potential (fig. 1). The fastest growth rates observed will indicate periods of least competition. A random sampling of stumps over the proposed thinning area can quickly suggest what growth rate to expect.

Increment cores from young trees or cross-sections from saplings, grown for some time without competition, also provide good working estimates.

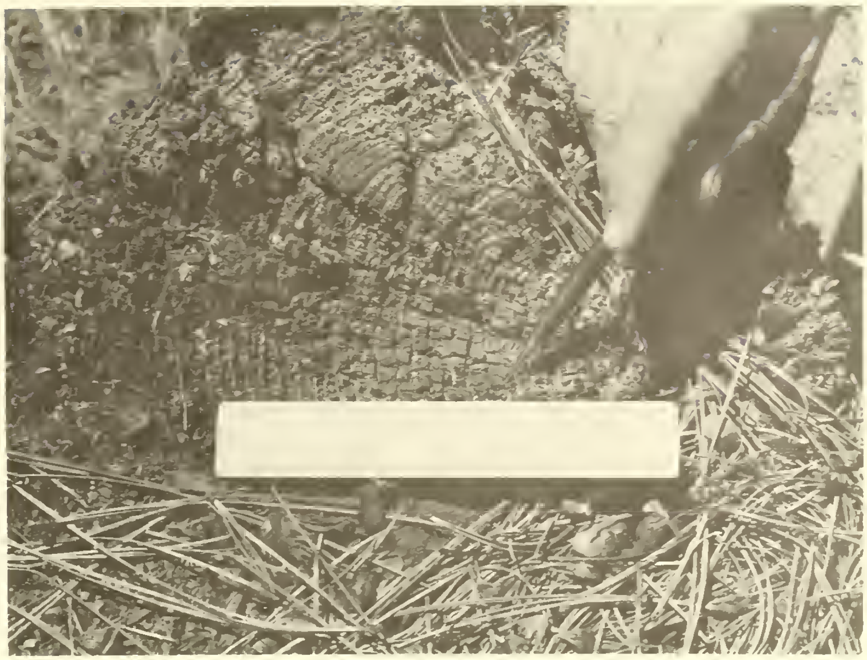


Figure 1.--Stump which suggests a 6-ring-per-inch site growth potential.

As a last resort, and only when direct observations fail to satisfy the stand manager, site index measurements may be used. The following tabulation gives preliminary RPI growth rate potentials for ponderosa pine site index classes (Meyer 1938). The values are based on limited field observations, and should be considered tentative until revised and refined by more extensive studies.

Site index class		*RPI*
Base age 100	*Base age 50*	
30-70	17-43	10-6
70-110	43-73	6-4
110-130	73-89	4-3
130-150	89-105	3-2
150+	105+	2 or less

Naturally, the tree vigor at time of thinning will dictate how long the tree requires to reach the RPI potential. Crown length and vigor classes could add some refinement in estimating this factor. For simplification, these refinements are not considered in this general presentation of the method.

Thinning of large areas is desirable to insure economical future harvest offerings. Large areas imply a range in site conditions. To assure a uniform stand size at a proposed harvest date, different thinning standards may be necessary in parts of a large area. Area maps and records should show site index and RPI growth data to balance thinning needs over cutting units.

Step 2.--Developing Basal Area Stocking Standards

Basal area per acre stocking standards must be developed for each species and site combination. Experience has shown many thinnings to be overly conservative. Growth rates have increased after thinning, but spacing was generally too close to permit trees to respond fully.

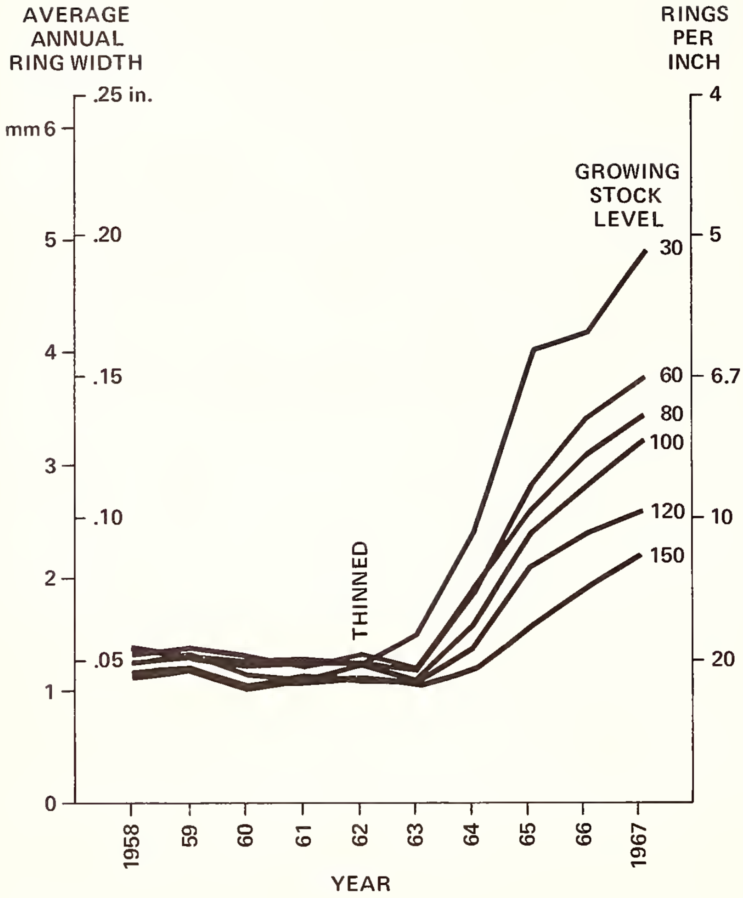


Figure 2.--Comparison of annual ring width of young ponderosa pine before and after thinning to different growing stock levels in the Taylor Woods plot on the Fort Valley Experimental Forest, Site Index 88 (Minor 1964). (Adapted from Schubert 1971).

Schubert (1971) shows that on ponderosa pine site index 88_{100} (base age 100) (Minor 1964; comparable to Meyer 1938, 68_{100}) competition is starting when stands attain 40 to 45 ft^2 of basal area (fig. 2). Stands thinned in 1962 to about 19 ft^2 basal area (growing stock level 30; Myers 1967) showed growth rates increased from 20 to 5 rings per inch in 1967. Rates were still short of the maximum growth rate the site could support when basal area was 30 ft^2. At growing stock level 60, growth was slowing in 1967 when basal area was 46 ft^2.

On the Spokane Indian Reservation (USDI, Bureau of Indian Affairs 1972), where the ponderosa pine site index averages about 90_{100} (Meyer 1938; comparable to Minor 1964, 99_{100}) when average all-age sawtimber basal area approaches 45 ft^2 the gross annual growth is predicted to be 275 board feet (Scribner) per acre. This is 94 percent of the mean annual increment according to normal yield tables for even-aged stands (Meyer 1938). Differences in production between even-aged and all-aged systems are assumed to be insignificant (Baker 1934, p. 209).

These two studies suggest that 45 to 55 ft^2 may be reasonable basal area stocking standards for Meyer's site index 70-110_{100}. Basal area is increasing about 4 ft^2 per year at this stocking level so that a later change in stocking standard, for instance, from 55 to 64 ft^2 represents just 3 more years of growth. At rates of 5 rings per inch, the growing stock level 30 stand at Fort Valley will reach 45 ft^2 of basal area by 1974. Growth from 19 to 45 ft^2 of basal area in 12 years illustrates the stand growth potentials and suggests that heavy thinning will be necessary to sustain high growth rates on individual trees.

Interim ponderosa pine basal area stocking standards for the onset of competition related to site index (Meyer 1938) are:

Site index$_{100}$	*Basal area*
	ft^2
70	45
90	50
110	55

Step 3.--Estimating Economic Size and Merchantability Limits

A stand manager must try to predict what the minimum merchantable size will be when he reenters the stand to make his first commercial thinning. One realistic management objective is to obtain a return from the stand at the earliest possible date and insure the continued rapid growth of the residual stand. In general, a commercial thinning shortly after the stand reaches the merchantable limit will more than cover costs. Frequently part of past investments in precommercial thinning, regeneration, and "land rent" can be recovered also. This effectively reduces interest costs, whether implied (public lands) or an actual account charge (private land).

On the Boise National Forest in Idaho, the minimum merchantable conifer is about 10 inches d.b.h. One sale of ponderosa pine, with an 8-inch size limit, was cut at Boise Basin Experimental Forest in late 1971. At the Fort Valley Experimental Forest, Arizona, ponderosa pine trees 6 inches d.b.h. are merchantable for pulpwood (Schubert 1971).

Economic maturity guides (Teeguarden 1968) for site index 157_{100} (Arvanitis and others 1964, comparable to Myers 1938) suggest we should not carry ponderosa pine stands dedicated to sawtimber production beyond 16 inches d.b.h. The Forest Service Manual (2415.21 1972) suggests 17 to 20 inches. Where other objectives override, such as in travel influence zones, responses of larger diameter trees may still be estimated with this system. Naturally, older trees will not attain the site rings per inch growth potentials.

Step 4.--Establishing the Reentry Year

The proposed reentry year is critical to the success of this method. The treatment prescription is determined by the time between the last precommercial thinning and the first commercial thinning. We work backwards from a future objective. An important implication is: *Once a stand is brought under management there is a commitment to follow through with future harvests.* This is doubly important if treatment is necessary to sustain growth rates where forestwide harvest levels have been based on the allowable cut effect (Schweitzer and others 1972).

Realistically, the level of refinement of today's growth estimates suggests that the proper reentry year may vary by ±20 percent of the time period between harvests. If the first commercial harvest (reentry date) is proposed for 12 years after thinning, it would be reasonable to check the stand ring-per-inch growth rates and basal area at 10 years and to adjust the reentry year to 13 or 11 if necessary. At this time, a very precise reentry date can be proposed. The value of such precision for management practices should not be overlooked; establishment of a proper reentry year and adherence to it are necessary to maintain high tree growth levels and to assure recovery of earlier investments.

Step 5.--Estimating Minimum Operable Volume Per Acre

A logger must have a majority of paying operations to stay in business. Both size of material and volume per acre removed are important. Of course, equipment should be geared to efficiently handle the size of material being logged.

Volume per acre influences costs and returns for each landing or loading setup, and other costs which are prorated on an area basis. We have little data to suggest the "break-even" volume per acre. It appears that efficient and flexible operations are possible with 1 to 1.5 thousand board feet per acre on easy ground with good access and mills nearby. The land manager must provide the "break-even" estimate for each situation on the basis of local conditions.

GRAPHIC SOLUTIONS WITH PONDEROSA PINE

All five factors may be brought together in a single graph having 2-cycle logarithmic scales (fig. 3). The stand density index of Reineke (1933) follows the same form as figure 3. Reineke's units are relatives, *i.e.* percent of normal stocking, based on a yield table, while these units are in absolute values, *i.e.* square feet of basal area. Meyer (1938) adjusted the stand-density index to fit his data for ponderosa pine and used, as the index values, the number of stems at 10 inches d.b.h., *i.e.* stand-density index of 200 means 200 10-inch trees or a comparable number for other diameters. Meyer's adjustment for curvature has little significance in the stocking range considered here. The physical relationships of d.b.h., stems per acre (SPA), spacing and stand basal area (BA) are the base:

$$\text{Log SPA} = 5.20788 - 0.99455 \text{ Log } (\text{DBH}^2) + 0.99451 \text{ Log BA}$$

and, spacing in feet (FT):

$$\text{FT} = \sqrt{43560/\text{SPA}}$$

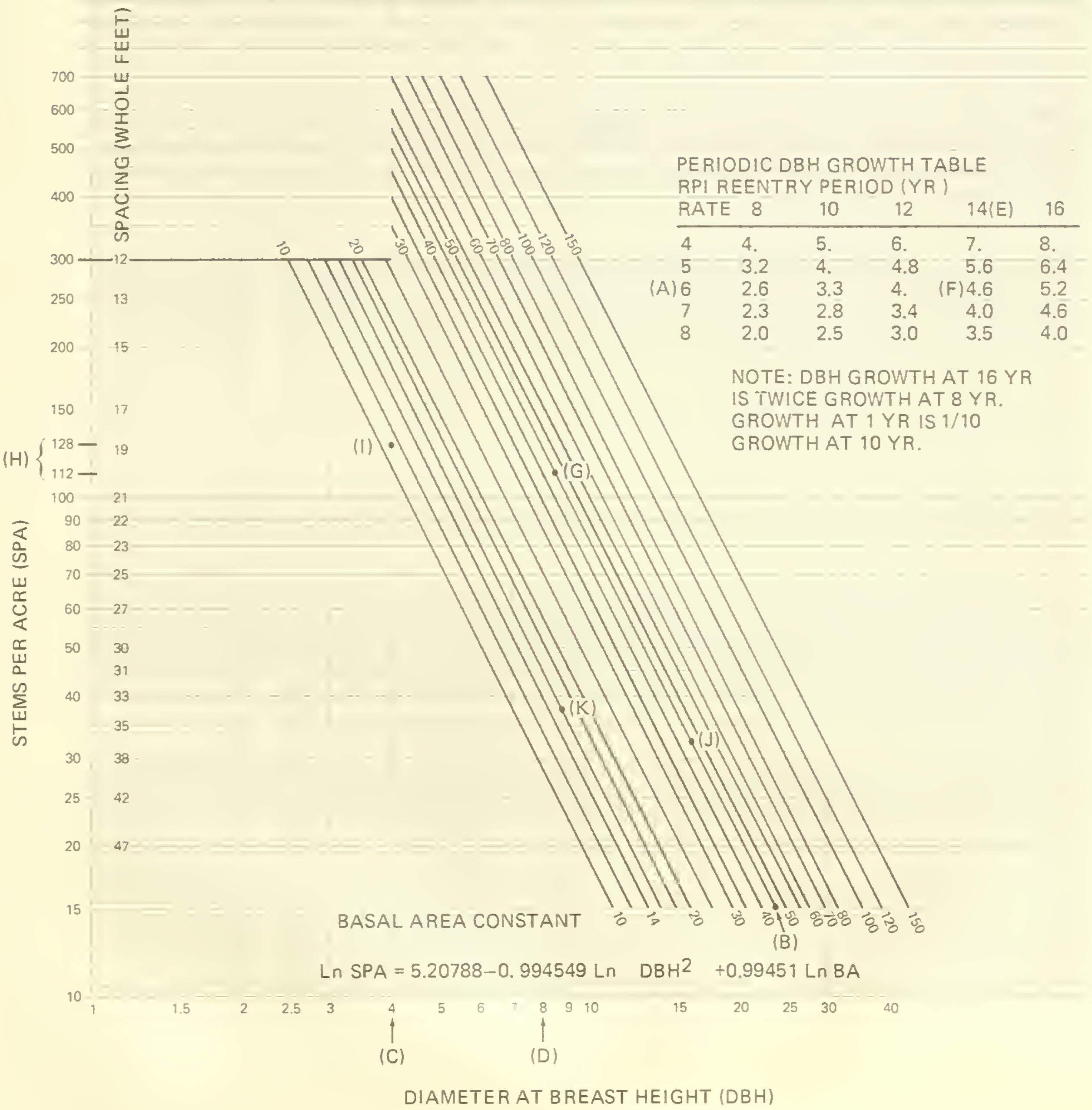
D.b.h. growth for representative RPI rates and reentry periods are inset in a table. Estimates of rings-per-inch growth potential over time (reentry period), the basal area stocking standard, and the merchantability and operable volume limits are specified for each management situation.

Example

Let's see how the model for precommercial thinning in an even-aged ponderosa pine stand works. Letters in parentheses in this example refer to the same letters on figure 3. We will assume a set of data for one stand of uniform Site Index 70_{100} or 43_{50} (Meyer 1938). Stump observations suggest a 6-ring-per-inch growth rate potential (A). We assume that 45 ft^2 basal area is the stocking limit (B). The stand presently averages 4 inches d.b.h. (C) on the 100 largest trees and is 30 years old. Estimated tree merchantability in 10+ years is 8 inches d.b.h. (D). At 6 rings-per-inch (RPI) the stand will reach the estimated merchantability limit in 12 years.

$$(8 \text{ inches} - 4 \text{ inches}) \times 1/2 \times 6 \text{ RPI} = 12 \text{ years.}$$

Notice that we are starting with a future objective and point in time and will work backwards to the thinning standard.



PERIODIC DBH GROWTH TABLE
RPI REENTRY PERIOD (YR)

RATE	8	10	12	14(E)	16
4	4.	5.	6.	7.	8.
5	3.2	4.	4.8	5.6	6.4
(A) 6	2.6	3.3	4.	(F) 4.6	5.2
7	2.3	2.8	3.4	4.0	4.6
8	2.0	2.5	3.0	3.5	4.0

NOTE: DBH GROWTH AT 16 YR IS TWICE GROWTH AT 8 YR. GROWTH AT 1 YR IS 1/10 GROWTH AT 10 YR.

$$\text{Ln SPA} = 5.20788 - 0.994549 \text{ Ln } \text{DBH}^2 + 0.99451 \text{ Ln BA}$$

Figure 3.--Average diameter at breast height, stems per acre/spacing relations for constant basal area factors. SPA = stems per acre; DBH = diameter at breast height.

Let's assume that plans for year 12 (reentry period) prevent us from making the thinning; *i.e.*, thinning crews, processing plant capacity, or area for allowable cut are fully committed. We must defer treating this stand for 2 more years--to year 14 (E). By year 14 we will have added 4.6 inches of d.b.h. growth (F) and we want to arrive at our basal area standard of 45 ft^2 with trees 8.6 inches d.b.h. (G). Looking to the vertical axis we find there will be 112 stems per acre spaced an average of 19.7 feet apart (H). To check, an 8.6-inch tree has 0.4034 ft^2 basal area here. Hence,

$$45\ \text{ft}^2\ \text{BA}/.4034\ \text{ft}^2 = 112\ \text{trees per acre}$$

Over a 14-year period we can assume there will be some mortality. Assuming 1.0 percent per year mortality for 14 years, compounded annually, the interest factor is 1.145 (Marty and Neebe 1966; Forbes 1956; or other forest management texts). Thus, including predicted mortality we should thin to leave:

$$112\ \text{SPA} \times 1.149\ \text{factor} = 128\ \text{SPA} \quad (\text{H})$$

Average spacing should be:

$$\sqrt{43560\ \text{ft}^2\ \text{per acre}/128\ \text{SPA}} = 18.5\ \text{ft between trees}$$

A tree 4 inches in d.b.h. has 0.0873 ft^2 basal area. Thus after thinning to 128 SPA the basal area stocking should average:

$$128\ \text{SPA} \times 0.0873\ \text{ft}^2 = 11.2\ \text{ft}^2\ \text{BA}_6\text{--about } 11\ \text{ft}^2\ (\text{I}).$$

In summary, we have a stand of 4-inch trees capable of growing at a 6-ring-per-inch rate. Thinning these trees now to 11.2 ft^2 BA (128 SPA) should, with 1 percent mortality per year, bring the stand to 45 ft^2 BA in 14 years with 112 stems per acre averaging 8.6 inches d.b.h.

DISCUSSION

This interim method for setting thinning standards can help forest managers recognize tree growth potentials and insure sufficient spacing to permit full stand responses over the desired time span. These standards should improve economic returns by tailoring the stand to fit the growth period and site potentials and by insuring the fullest stand response for the thinning investment. Volume growth will occur on fewer stems, shortening the period to reach prescribed size objectives.

Basal area standards may be modified to attain other objectives. Steep slopes may require heavier stocking to control erosion. Lighter stocking may produce more forage for wildlife winter range or cattle allotments.

Logging disturbance of slope-protective vegetation may dictate longer growth periods. Greater logging costs may also suggest longer growth periods to increase the volume cut per acre.

If maximum periodic diameter growth is not one of the objectives of a thinning, the forest manager must establish other relationships to reach his objective. Results from the western regional growing-stock-level studies will help establish stocking-diameter growth relationships to achieve less than maximum periodic diameter growth.

Tree and wood quality characteristics have not been considered in this method. Consideration of relative wood density and uniformity of growth rings as influenced by growth rates and stocking should be included as data become available. Branch characteristics and tree form as related to stocking are other areas needing study before inclusion.

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